PHOTO INTERPRETATION REPORT

USGS-NPS VEGETATION MAPPING PROGRAM

SCOTTS BLUFF NATIONAL MONUMENT

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USGS-NPS VEGETATION INVENTORY AND MAPPING PROGRAM
AERIAL INFORMATION SYSTEMS PROJECT REPORT

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I. INTRODUCTION

The National Park Service (NPS) in conjunction with the USGS Biological Resources Division Center for Biological Informatics has created a program to "develop a uniform hierarchical vegetation methodology" at a national level, and to create a geographic information system (GIS) database for the parks under its management. The purpose of the data is to document the state of vegetation within the NPS service area during the 1990's thereby providing a baseline study for further analysis at the Regional or Servicewide level. Aerial Information Systems (AIS) was subcontracted by Environmental Systems Research Institute (ESRI), the prime contractor, to perform the photointerpretation for the program. The Nature Conservancy (TNC) was subcontracted by ESRI to conduct the field sampling effort and to support the development of the National Standard Classification.

Several parks, representing different regions, environmental conditions, and vegetation types, were chosen to be part of the prototype phase of the program. The initial goal of the prototype phase is to "develop, test, refine, and finalize the standards and protocols" to be used during the production phase of the project. This includes the development of a standardized vegetation classification system for each park and the establishment of photointerpretation, field, and accuracy assessment procedures.

Scotts Bluff National Monument was designated as one of the prototype parks. The monument is located in the high Great Plains. It contains prairie, bluff, and riverine environments, with vegetation types that include upland woodland, prairie grassland, and riverine woodland and grassland. AIS was responsible for the photointerpretation of the vegetation units and rectification of those units to a base. TNC directed the field sampling effort and the classification assignments. Working with the field biologists from TNC, AIS photointerpreted the vegetation units from stereo paired, natural color photography.

II. SCOTTS BLUFF NATIONAL MONUMENT - GENERAL DESCRIPTION

The National Park Service created Scotts Bluff National Monument in 1919. The monument occupies approximately 3000 acres adjacent to the North Platte River in Scotts Bluff County, Nebraska.

The primary focus of Scotts Bluff National Monument is two-fold. The first is as an historic site, the second as a natural area. Historically, the area is located along major 19th century overland routes to the Pacific Northwest and California. The bluffs were conspicuous landmarks from which the travellers noted their progress. A portion of the Oregon Trail is located in the monument, running through Mitchell Pass. In addition, a portion of the Mormon Trail runs along the north bank of the North Platte River, just outside the park.

As a natural area, the monument contains several remnant tablelands or bluffs of the ancient Great Plains, rising about 600 feet above the floor of the prairie below. The area has had limited historical disturbance. Currently the monument contains an Oregon Trail Museum and Visitor Center, a roadway to a parking area at the top of Scotts Bluff, hiking trails on the top of Scotts Bluff, a trail from the top of Scotts Bluff to the Visitor Center, a biking trail on the eastern side of the monument, a road along the irrigation canal in the northern part of the monument, and a path along the Oregon Trail.

The monument is surrounded on three sides by agriculture in the form of cropland and pastureland. The cities of Gering and Terrytown are located on the east side of the monument. The city of Scottsbluff is located across the North Platte River northeast of the monument. State Highway 92 bisects the monument from east to west. A railroad right-of- way skirts the southern edge of the floodplain.

Scotts Bluff National Monument contains four major geomorphologic features:

- The North Platte River floodplain, includes the river, sand bar, shallow side and abandoned channels, and river terraces. It is a major riparian area composed of woodland, shrubland, herbaceous, and unvegetated areas.

- The badlands, located between Scotts Bluff and the river, is a rugged relatively unvegetated area, with occasional remnant flat prairie tops.

- The bluffs are composed of two major features, Scotts Bluff and South Bluff. The bluffs can be further subdivided into their tops, sideslope escarpments, and toe or talus slopes. The north-facing slopes, upper slopes and tops contain woodland. The remaining slopes are primarily moderate to low density grassland and relatively unvegetated rock outcrop.

- The prairie can be subdivided regionally into the northwest prairie, the western prairie, the eastern prairie, and the southern prairie. The prairie is composed of grassland with scattered shrubs in places. Steep-sided ravines dissecting the prairie contain shrubland. Some ravines also contain woodland, grassland, relatively unvegetated rock outcrop, or exposed soil with low density grassland.

All areas are accessible by hiking. The top of Scotts Bluff is reached either by the bluff road or by a hiking trail. Unmaintained roads follow part of the floodplain, the railroad right-of-way, and the irrigation canals in the northern, eastern, and southern parts of the monument.

The following is a brief and general description of the eight major regions and their associated vegetation types.

NORTH PLATTE RIVER FLOODPLAIN

The vegetation of the floodplain is related to the annual flow of the North Platte River. Conditions may vary from year to year, mainly affected by climatic factors such as seasonal rainfall and snowmelt. The configuration of the river channel, side channels, and abandoned channels may change over time due to catastrophic flooding, erosion, and deposition.

Sand bar areas at the edge of the river contain little vegetation. Abandoned channels contain saturated mudflats, Typha latifolia, and some Salix exigua. The lower floodplain terrace contains sparse, dispersed, and open woodland composed of Populus deltoides, Salix amygdaloides, Fraxinus pennsylvanica, and Acer negundo. The open areas of the woodland contain dense areas of forbs and grasses. Clumps of Salix exigua also occur on the lower floodplain terrace where tributary streams enter the floodplain. There does not appear to be an upper floodplain terrace south of the river at the monument.

THE BADLANDS

The badlands are located at the northeast part of the park, between the floodplain and Scotts Bluff. The rugged dissected alkaline sandy clay slopes contain little vegetation. Most of the vegetation, if any, are located within the draws and ravines, which are about ten to thirty feet in depth. Moderate to low density shrubland ravines and lowlands contain Symphoricarpos occidentalis, Rhus aromatica, and a variety of alkaline shrubs. Lowland grasslands contain Pascopyrum smithii, Poa pratensis, Calamovilfa longifolia, and Nassella viridula. Remnant prairie tops within the badlands contain Carex filifolia and Stipa comata.

The Gering Canal bisects a portion of the badlands. Artificial seepage, through leakage of the canal, has contributed to stream flow in some of the ravines and draws, creating a more lush or denser growth of forbs, grasses and shrubs. The increased flow has also been able to support trees in some places. The shrubs and grasses are similar to those described above. The trees, located adjacent to the canal in the ravines, are mainly Populus deltoides, Fraxinus pennsylvanica, and Salix amygdaloides.

SCOTTS BLUFF

Scotts Bluff is a prominent "star-shaped" body composed of siltstone and sandstone rising vertically about 600 feet above the prairie. The vegetation of Scotts Bluff varies, and is dependent on aspect, elevation, and soil depth. Dense to open stands of juniper woodland, composed of Juniperus scopulorum occupy several ravine areas on the upper to middle slopes on the north side of the bluff.

Open, dispersed, and sparse density pine woodland composed of Pinus ponderosa are located on the top and upper slopes of Scotts Bluff. The pines are also scattered throughout the northern exposure of the bluff. Juniperus scopulorum is scattered throughout the pine woodland. The understory of the pine woodland varies from grass, shrub and grass, to relatively unvegetated rock outcrop, and a grass/rock outcrop mix. Most grasses at the top of the bluff are Bouteloua gracilis, Calamovilfa longifolia, and Stipa comata. The sedge Carex filifolia is also present. Shrubs include Ribes cereum and Rhus aromatica. Scattered Yucca glauca and Bouteloua curtipendula also occur.

The upper to middle slopes of Scotts Bluff contain exposed rock outcrop alternating with thin shallow ledges of soil containing moderate to low density grasses including Bouteloua gracilis, B. curtipendula, Calamovilfa longifolia, and Elymus lanceolatus lanceolatus. Scattered shrubs including Rhus aromatica and Artemisia frigida also occur in places. The upper slopes also contain scattered Opuntia spp. and Yucca glauca. Present in the upper to middle slopes are wide vertical cliffs of sandstone with little or no vegetation.

The lower slopes of Scotts Bluff contain Bouteloua gracilis and Stipa comata, with increasing Carex filifolia lower down the slope. The density of the scattered Yucca glauca increases, though still not significantly. Scattered Krascheninnikovia lanata also occurs in low densities at the bottom of the lower slopes. Some shallow steep ravines contain Symphoricarpos occidentalis and/or Rhus aromatica. In many places, at the bottom of the toe slopes, especially where the bluff protrudes out onto the prairie, are rock outcrop areas with little or no vegetation.

SOUTH BLUFF

Geologically, South Bluff is similar to Scotts Bluff. South Bluff, however, trends in a linear east-west direction, with a perpendicular northern protrusion pointing toward Scotts Bluff. The narrow gap between the end of the protrusion at Sentinel Rock and the southern end of Scotts Bluff at Eagle Rock form Mitchell Pass. The South Bluff protrusion contains a lower ridge area referred to as Coyote Pass. The top of South Bluff is also much narrower than that of Scotts Bluff. The eastern end of South Bluff gradually lowers in elevation, forming isolated prominences such as Dome Rock. The western end remains of significant elevation above the prairie.

The vegetation of South Bluff is similar to Scotts Bluff. The elongated northern exposure of South Bluff east of Coyote Pass contains moderate to low density pine woodland composed of Pinus ponderosa. West of Coyote Pass the pine woodland is of moderate to high density. A moderate density shrubland community composed of Cercocarpus montanus occurs on the eastern and western flanks of Coyote Pass.

The upper and middle slopes of South Bluff are similar to Scotts Bluff, containing alternating rock outcrop and ledges of shallow soil with mainly grasses. The wide vertical cliffs of sandstone are also present. The southern exposure of South Bluff contains sparse to rare densities of Rhus aromatica.

The lower slopes are also similar to Scotts Bluff, but do not contain as much Yucca glauca or Krascheninnikovia lanata. Symphoricarpos occidentalis and Rhus aromatica, however, are present in some of the shallow sideslope ravines. Juniperus scopulorum occupies some wide sideslope ravines on the northern exposure.

NORTHWEST PRAIRIE

The prairie northwest of Scotts Bluff is located between the floodplain/railroad right-of-way and the Gering Canal. The area was historically disturbed by grazing, farming, and dumping. It is composed of flat level prairie, with many deep ravines. The prairie gradually grades eastward into the badlands. The prairie tops are composed of grassland containing Stipa comata, Pascopyrum smithii, Calamovilfa longifolia, Bromus spp., Carex filifolia, and some Krascheninnikovia lanata. The ravines, about twenty to thirty feet in depth, are primarily eroding exposed soil. The ravine sides are sparsely vegetated with forbs, Artemisia frigida, Calamovilfa longifolia, and Bromus spp. The ravine bottoms contain Calamovilfa longifolia, Bromus spp., and some Rhus aromatica.

WESTERN PRAIRIE

The prairie west of Scotts Bluff is gently rolling terrain, with ravines dissecting the southern portion. The vegetation is primarily composed of Carex filifolia and Stipa comata. Colluvial disturbed areas contain Calamovilfa longifolia. Krascheninnikovia lanata occurs in sparse or rare densities in some places. Areas with sandier soil contain sparse to rare densities of Artemisia filifolia with Andropogon hallii and Calamovilfa longifolia. There are a number of heavily disturbed areas containing forbs and Bromus spp. Several historically disturbed areas in the northern and western portion of this prairie have been reseeded with monocultures of Agropyron cristatum or Bouteloua curtipendula. They also contain areas of forbs and Bromus spp. Calamovilfa longifolia circles and Pascopyrum smithii-Bromus spp. disturbance areas occur in patches throughout the prairie.

The ravines vary in depth and width from ten to thirty feet. The sideslopes of the ravines vary in vegetation, from relatively unvegetated rock outcrop, to sparsely vegetated eroding soil composed of Calamovilfa longifolia and forbs. Other ravine sideslopes contain sparse to dense covers of Rhus aromatica and other shrubs. The ravine bottoms contain either grassland composed of Pascopyrum smithii, Poa pratensis, and Calamovilfa longifolia, or shrubland containing Symphoricarpos occidentalis, Rhus aromatica, and other shrubs. The ravines in the southern portion of the western prairie contain planted Juniperus virginiana, and Pinus ponderosa. Pinus ponderosa also occupies much of the prairie interfluves at their transition with South Bluff. A very wide north-south trending ravine drainage borders the western boundary of the park. The wide flat bottom contains Pascopyrum smithii, Poa pratensis, Nassella viridula, Calamovilfa longifolia, forbs, and many large areas of Bromus inermis. The sideslopes contain many occurrences of sparse Artemisia filifolia, with forbs, Andropogon hallii, Calamovilfa longifolia, and eroding exposed soil.

The southwestern end of the study area, north of South Bluff is outside the monument. It is currently a heavily grazed area containing Stipa comata, with patches of forbs, Bromus spp., Pascopyrum smithii, and Calamovilfa longifolia.

EASTERN PRAIRIE

This portion of the prairie has been heavily disturbed. It is flat to gently rolling terrain, with many ravines dissecting the southern portion. There is a large lowland area just east of Mitchell Pass where the Visitor Center is located. The prairie varies in composition, from Stipa comata and Carex filifolia, to areas of primarily Stipa comata or also containing Calamovilfa longifolia.

Krascheninnikovia lanata and Yucca glauca occur in rare to sparse density patches throughout the area. Several seeded disturbed areas contain monocultures of Pascopyrum smithii, Agropyron cristatum, or Schizachyrium scoparium. Some seeded areas and otherwise heavily disturbed areas contain Bromus spp., Ericameria nauseosa ssp. nauseosa var. nauseosa, Kochia scoparia and/or Ulmus pumila. Other degraded prairie areas contain Pascopyrum smithii and Bromus spp.

The ravines vary in depth and width, but are not as deep as those in the western prairie. The ravines contain dense to sparse shrubland composed of Symphoricarpos occidentalis, Rhus aromatica, with some Shepherdia argentea, Ribes aureum, and Prunus virginiana. Some ravines also contain planted Juniperus virginiana. The sideslopes of the ravines contain Rhus aromatica, Calamovilfa longifolia, Stipa comata and/or relatively unvegetated rock outcrop. The grassland in the ravines and the wide lowland area contain Pascopyrum smithii, Poa pratensis, Calamovilfa longifolia, and Schizachyrium scoparium. North and east of the Visitor Center, the lowland prairie area contains forbs and Bromus spp. There is one seep area at Scotts Spring that contains Typha latifolia, Salix exigua, Prunus virginiana, Rhus aromatica and Carex spp.

SOUTHERN PRAIRIE

The prairie south of South Bluff slopes gently down from the base of the bluff. It forms a narrow band between South Bluff and the southern park boundary. Its vegetation has been heavily grazed and disturbed. It primarily contains Stipa comata, with large occurrences of Calamovilfa longifolia, Bromus spp., and forbs.

III. SUMMARY OF MAPPING EFFORT AT SCOTTS BLUFF NATIONAL MONUMENT

The following section is a short outline, listed in chronological order, of the vegetation mapping effort at Scotts Bluff National Monument. For a detailed description of the tasks listed, refer to sections IV, V, and VI.

- April 1995
  - Initial Meeting at Scotts Bluff National Monument
- June 1996
  - Project Set Up
    - Develop flight line index, photo layout
    - Set up of photo overlays
    - Delineation of preliminary study area boundary
- July 1996
  - Preliminary Delineation of Photo Signature Units
- August 1996
  - Receipt of Finalized Study Area Boundary
  - Field Preparation
  - Photointerpretation Field Effort
    - Field effort

- In-field meeting with Ralph Root
- Overview perspective with Steve Rolfsmeier

August to September 1996
- Field Revisions
- Photointerpretation and Coding of Vegetation Attributes
  - Development of working photo signature key
  - Photointerpretation of alliance/community association, height and density
  - Follow-up discussions with Steve Rolfsmeier and Jim Drake

September 1996
- Receipt of Revised Vegetation Classification Document

October to November 1996
- Revision of Working Photo Signature Key (based on revised classification)
- Data Conversion
  - Basemap production
  - Manual rectification
  - Manuscript map preparation
  - Polygon label ID
  - Attribute input
  - Scanning and vectorization
  - Edit plot QC (photo signature, height, density)
  - Final processing

November 1996
- Georeferencing and Rectification of Data
- Final Alliance/Community Association and Pattern Assignment
  - Conversion of signature code to alliance/community association classification
  - Interpretation of pattern
  - Attribute encoding of pattern
  - Edit plot QC (alliance/community association, pattern)
- Delivery of Data Files to ESRI

December 1996
- Receipt of Final Classification, with Vegetation Key, and Descriptions (with modifications)
- Final Documentation

August 1997
- Accuracy Assessment Field work

September - December 1997
- Accuracy Assessment Analysis

February 1998
- Mapping Meeting to discuss photo interpretation issues

March - June 1998
Updating of photointerpretation and mapped data

July- October 1998
Finalization of spatial database

IV. VEGETATION MAPPING AT SCOTTS BLUFF NATIONAL MONUMENT

One of the most important mandates of the Vegetation Mapping Program is the consistent capture and classification of vegetation types through the use of photointerpretation and field sampling methodologies. Mapping criteria and procedures developed during the first two prototype parks are still being tested and revised. The vegetation mapping of Assateague Island National Seashore and Tuzigoot National Monument utilized vegetation layer mapping. Layer mapping consisted of photointerpretation of individual vegetation taxa, then reaggregating them into the appropriate alliance classes. As the third prototype park, USGS determined that a different approach be used for mapping alliance/community association, height, density, and pattern at Scotts Bluff National Monument.

The following sections describe the tasks performed and methodologies used by AIS during the photointerpretation effort for Scotts Bluff National Monument.

Initial Meeting

A two-day meeting was held in April 1995 at the park headquarters. Its purpose was to bring together the project team members (USGS, AIS, TNC, and ESRI) with park personnel to discuss the Vegetation Inventory and Mapping Program and specific interests of the park. USGS conducted a presentation and discussion of the Vegetation Inventory and Mapping Program. Park personnel presented source documents and maps for possible use in the inventory mapping. A tour of the monument was conducted to familiarize the project team members with the existing general vegetation types, topography, and history.

During the meeting, imagery, basemaps, existing vegetation maps and other pertinent collateral materials were reviewed and evaluated. The team members discussed possible mapping and field sampling techniques. This included determination of the optimum time to conduct the field efforts, from a photointerpretation and field sampling perspective. The amount of park support (e.g., personnel, transportation, etc.) was also discussed. AIS submitted a Data Collection Report to ESRI summarizing the initial meeting and park tour.

In the summer following the initial meeting, TNC conducted field plot data collection and developed the draft document "Vegetation Classification of Scotts Bluff National Monument". As a result, the vegetation classification, vegetation key, and descriptions for Scotts Bluff National Monument were available before photointerpretation commenced. In the previous

USGS vegetation mapping projects, the TNC field plot data collection, and release of the draft vegetation classification, key, and descriptions did not occur until after photointerpretation was completed.

Development of Photointerpretation Mapping Procedures

The normal process in vegetation mapping is to conduct a field reconnaissance, map the vegetation units through photointerpretation, then conduct a field verification. The field reconnaissance visit serves two major functions. First, the photointerpreter keys the signature on the photos to the vegetation on the ground at each signature site. Second, the photointerpreter becomes familiar with the taxa, vegetation types, and local environments that occur in the study area. Park and/or TNC field personnel, who are familiar with the local taxa, vegetation types, and alliance/community associations, are present to help the photointerpreter understand these elements and their relationship with the local environments.

Upon completion of the field reconnaissance, the photointerpretation of the vegetation units commences. The mapping is conducted in accordance with the TNC vegetation classification and criteria. This is followed by a field verification session, whose purpose is to verify that the vegetation units were mapped correctly, and to answer any questions.

Three factors of the Scotts Bluff Project affected the development of the mapping procedures: First, due to the small size of the park, USGS tasked AIS for one rather than two field sessions at the monument. The lack of a second field visit meant that some means of identifying mapping questions prior to the single field effort had to be devised. Second, was the possibility of classification and criteria changes and/or additions resulting from the field effort and/or the photointerpretation. Resolution of such issues could result in a major remapping effort, depending on the magnitude of the modifications. It would also delay the photointerpretation, mapping, and data conversion process. Third, the schedule from the field effort to the photointerpretation and data conversion completion was short.

Taking these factors into consideration, the approach for mapping at Scotts Bluff was devised. Photointerpretation of the vegetation before the single field session was ruled out as an option. A draft classification document was available, but the photointerpreter had not yet visited the park or interacted with the park or TNC field personnel. To photointerpret vegetation prior to the field visit had the potential to result in a major mapping revision effort. This was especially possible if there were changes and additions to the TNC vegetation classification and criteria as a result of the field visit. However, because of the small size of the park, it was possible to delineate all, rather than selected photo signature units prior to the field session. The units would be photointerpreted and coded for their vegetation attributes after the field, when signature correlations were established and any classification changes and additions were resolved.

Since the park is small and most areas within it are accessible, it would be possible to visit many points during the field session. The framework of photo signature units would aid in providing finite photo units of reference in the field to correlate to the ground units, thus facilitating field logistics. This process would help alleviate the fact that no second field session for verification purposes would be conducted.

By photointerpreting the previously drafted photo signature units after returning from the field, the interpreter would have far less linework to delineate. This would aid in reaching the projected schedule, especially if there was a delay due to classification and/or criteria additions and changes.

It was determined that pattern, being more of a general vegetation attribute, would best be interpreted at the completion of the vegetation mapping. All mapped features could be viewed in context of each other over the entire landscape of the park in order to assess the pattern for a given alliance/community association.

Development of Photointerpretation Mapping Criteria

Since mapping for the Vegetation Inventory and Mapping Program had begun, a standardized program-wide mapping criteria was being developed. Mapping criteria is a set of documented working decision rules used to facilitate the maintenance of accuracy and consistency of interpretation in the database. They assist the user in understanding the characteristics, definition, and context for each vegetation category.

The mapping criteria for Scotts Bluff National Monument is composed of three parts: the standardized program-wide general mapping criteria, the park specific mapping criteria and the working photo signature key, and the classification descriptions. The following is a detailed description of the criteria used during the photointerpretation of Scotts Bluff National Monument.

- General Mapping Criteria

  The mapping criteria listed below is a modified version of that developed during the Assateague Island National Seashore mapping effort. The criteria will serve as the standard for future photointerpretation efforts in the Vegetation Inventory and Mapping Program to ensure a consistent standard of mapping on a nationwide basis.

  - Height

    Height describes average height of the life form of the specific alliance/community association unit. If there are significant height differences within an alliance/community association unit, then the unit can be subdivided to reflect those differences, provided they meet the minimum mapping unit (mmu) resolution.

    - Height Categories

      <0.5 meters
      0.5 - 2 meters
      2 - 5 meters
      5 - 15 meters
      15 - 35 meters
      35 - 50 meters
      >50 meters
      Not Applicable

- Height Mapping Criteria

    - To determine the average height of the vegetation of the same life form, determine which percentage of the vegetation is at what height. If 10% of the trees are 30m tall and 50% are 36m tall, then they will fall into a height class category of 35-50m. If 80% of the trees are 30m tall and 20% are 36m tall, then the height class category assigned to the polygon will be 15-35m.

    - When there are seedlings and mature growth of the same species, the dominant growth form will be the determining factor. For instance, if a polygon contains Pinus palustris seedlings <.5m tall and mature P. palustris trees 30m tall, the dominant cover type will determine the height assignment, i.e., if the 30m tall trees compose >50% of the tree cover, then the height class category for the trees will be 15-35m.

- Density

Density refers to the spacing of plants in the landscape. It represents the total coverage based on the percentage of crown or canopy cover. This figure is a qualitative estimate based on the aerial photography. Two methods are used to determine densities from aerial photographs, Absolute and Relative (Continual) Density. Absolute density refers to the sum total of the visible plant and non-vegetative cover within a given mapping unit. The total density cover for all visible over-, mid-, and understory vegetated and non-vegetated surfaces must equal 100% present. The unvegetated areas are not delineated unless they can be delineated at the project minimum mapping unit (mmu). Vegetation not visible on the aerial photograph is not considered as part of the total plant density. For example, in a closed canopy forest the understory grasses and shrubs are not visible, therefore only the tree overstory is visible and the density class is based on the total tree cover present.

Relative density is used when the aerial photography allows the interpreter to see the understory vegetation due to the environmental conditions at the time of the photography or when detailed field notes are available. When mapping relative density, it is possible to arrive at total vegetation cover percentages well over 100%. For example, using winter photography to capture leaf-off conditions, a closed-canopy deciduous forest (over 60% crown cover) is visible along with the shrub and grass understories. In addition to the 60-100% tree cover, shrub and grass understory may make up an additional 60-100% understory cover, totaling at least 120% vegetation cover for that mapping unit.

Absolute crown density is normally the most accurate way of estimating plant coverage and will be used to determine the percentage of vegetation cover within a polygon unless noted otherwise in the park specific mapping criteria. In certain park specific situations where understory needs to be mapped, relative density estimates will be addressed if there is sufficient data. At the very least, aerial photography showing leaf-off conditions is necessary when mapping relative crown density.

For Scotts Bluff National Monument density describes average absolute crown density of the life form of the specific alliance/community association unit. If there are significant density differences within an alliance/community association unit, then the unit can be subdivided to reflect those differences, provided they meet the minimum mapping unit (mmu) resolution.

- Density Categories
  - Closed/Continuous >60% = Canopies overlapping, touching or nearly touching in most of the mapping unit.
  - Discontinuous 40%-60% = Canopies rarely touching, however spacing is fairly minimal, especially when plants are not evenly distributed throughout the polygon.
  - Dispersed 25%-40% = An open or parkland situation where large spaces occur between trees and shrubs, or where grasses are fairly sparse throughout the mapping unit.
  - Sparse 10%-25% = Trees or shrubs are widely spaced, scattered throughout the polygon, or are clumped in very small areas making up a small percentage of the entire vegetative cover.
  - Rare 2%-10% = Trees or shrubs occur only occasionally and usually do not make up enough percentage to be considered evenly dispersed. Grass coverage at this level is hard to detect on small scale aerial photography.
  - Not Applicable = Density does not apply.
- Density Mapping Criteria
  - To determine the absolute density, assign percentages to the different life forms visible on the aerial photo, including non-vegetated areas. The total percent cover of trees, shrubs, herbaceous and non-vegetated should add up to 100%. Convert the absolute density percentages into the appropriate density class.
  - Non-vegetated areas are not coded in the database unless they meet the minimum mapping resolution for the park and can be mapped as a stand-alone polygon. Otherwise, it is assumed that all vegetation polygons contain non-vegetated areas.
  - Consider the coverage pattern of the vegetation before assigning a density code to the polygon. Estimating densities is more straight forward when plants occupying a particular strata are evenly distributed throughout the mapping unit. However when polygons contain

populations of plants that are clumped or occurring only in portions of the polygon, the photointerpreter must consider the area not occupied by plant cover when determining coverage density. To ensure consistency, it is helpful to count the plants in polygons with clumped and unevenly distributed vegetation and then compare them to similar sized polygons with an even distribution of plant cover.

- The vegetation stature type and scale of the aerial photography will determine the visibility of individual plants. Trees are usually visible as individuals and with larger scale photography so are shrubs. However, grasses are rarely seen as individual plants, regardless of the scale of the photography.

- Dry grasses tend to be less dense than they appear on the aerial photographs. To accurately depict the densities, the percent cover for dry grasses should be adjusted downward. This means that if the percent cover falls at the lower end of a density category, the polygon should be assigned the next density class down. For example, if the percent cover = 25%, the polygon should be assigned a density category of sparse (10-25%) instead of dispersed (25-40%). If the percent cover falls within the middle of a density category, the polygon should be assigned that density class, i.e., if the percent cover = 35%, then the polygon is assigned to the density category dispersed (25-40%).

- The date of the aerial photography will also influence the densities assigned to vegetation types, especially herbaceous species. Subsequent field verification must take into consideration the following factors that can cause seeming discrepancies between the densities evident on the photo and those visible in the field:

- Seasonality - the density of most herbaceous plants is variable due to their annual growth cycle. Depending on the season the aerial photography was taken, a mapped unit could show a different density on the aerial photographs than is observed during an on-site visit at a different time of the year. Another effect of seasonality is leaf on/off conditions. Photos of forest or woodland areas with leaf on conditions obscure the understory. Photos of leaf off conditions would allow photointerpretation of the understory.

- Different years - the environmental conditions at the time of the photography (wet vs. drought years, flooding, etc.) may affect the densities seen during the on-site field visits.

- Pattern

  Pattern describes the distribution of vegetation across the landscape within a given alliance/community association polygon. Pattern of vegetation can be a reflection of the landform, soil, geology, climatic gradients, and/or elevational gradients. For the purpose of consistency in interpretation throughout the USGS vegetation mapping program, pattern describes the distribution of the life form of each specific alliance/community association unit. For example, the pattern class assigned to a shrubland community association will be based on the distribution of shrubs within that unit. Herbaceous vegetation and trees would not be considered as part of the patterning in this case. Minimum mapping unit (mmu) size for pattern is 10 acres.

  - Pattern Categories

    - Evenly dispersed = Pattern of life form is an even or almost even distribution of individuals or clumps.

    - Clumped/Bunched = Unevenly dispersed clumps of individuals.

    - Gradational/Transitional = A gradual thinning of the individuals or clumps as one moves from one area to another.

    - Alternating = The vegetation individuals or clumps occur in a regular repeating pattern.

    - Not applicable = Pattern does not apply.

  - Pattern Mapping Criteria

    - For Scotts Bluff National Monument, pattern was mapped after the final alliance/community association map was created. A plot of the alliance/community association polygons was made and each polygon was compared back to the aerial photography. The vegetation distribution within the polygon was coded with the appropriate pattern code. If a polygon contained more than one pattern type, the polygon was subdivided as needed. Minimum polygon size for pattern is 10 acres.

- Alliance/Community Association

  The assignment of alliance and community association to the vegetative cover is based on criteria formulated by TNC. In the case of Scotts Bluff National Monument, TNC provided AIS with the USGS-NPS document "Vegetation Classification of Scotts Bluff National Monument". The document contains a vegetation classification, vegetation key, and vegetation descriptions of each alliance/community association occurring in the monument. This document in conjunction with the photointerpretation field effort and photointerpretation process was the basis for mapping of the vegetation of the monument.

Modifications of the document that occurred at several stages throughout the mapping process were incorporated in the mapping and photointerpretation documentation.

- Aggregation

  Aggregation of multiple vegetative classes is necessary when below minimum mapping unit (mmu) vegetation types are present within a polygon.

  - Like life forms should be aggregated together; trees should be aggregated with other trees, shrubs with shrubs and herbaceous with herbaceous vegetation types.

  - Wet vegetation types should be aggregated with other wet vegetation types, regardless of life form class.

  - If a unit that is below minimum mapping resolution is completely surrounded by another vegetation type class, the unit is aggregated with the surrounding vegetation.

- Working Photo Signature Key

  A photo signature key is an important tool for maintaining consistency of interpretation. It correlates the physical descriptions of the photo signature with the appropriate vegetation type. A key may also describe other useful information which would be helpful with the interpretation. For Scotts Bluff National Monument, a preliminary or working photo interpretation key based on signature characteristics was developed for the mapping compilation as an interim product. A final deliverable alliance/community association photo signature key was created based on the information compiled in the preliminary key.

  The preliminary or working photo signature key was developed for Scotts Bluff National Monument after the field visit. The data gathered in the field was analyzed. The photos, field overlays, and field notes were reviewed and consistent correlations between signature and vegetation types were noted. Each photo signature was given a unique code. The working photo signature key was constantly revised and updated as photointerpretation progressed. The key, in table form, contained the photo signature code, photo signature description (color, texture, crown size, crown shape), context (supplemental useful information), inferred taxa, and inferred community association.

  After completion of the mapping, a final alliance/community association photo signature key was created from the information compiled on the working photo signature key. This key contained alliance/community association code, alliance/community association name, photo signature (describing the community association life form), height, context, and notes.

- Park Specific Mapping Criteria

  The park specific mapping criteria addressed items of specific interest to the park that were not covered under the general mapping criteria:

  - The minimum mapping unit (mmu) was established at 1/4 hectare. (The program standard is 1/2 hectare).

  - The mapping scale at Scotts Bluff National Monument was 1:12,000.

  - After analyzing the field data, a general correlation could be made between topography and vegetation types. As a result, the park was divided into four unique physiographic areas with a description of the typical vegetation types for each area. The regions are listed below:

    - North Platte River Floodplain
    - Badlands
    - Bluffs (Scotts Bluff and South Bluff)
    - Prairie

  - Since vegetation disturbance identification and restoration is an on-going goal of the park, knowledge of vegetation disturbance locations and their rehabilitation over time is important. Areas with highly disturbed vegetation containing exotic forbs, Bromus spp., and/or Bromus inermis can be discerned on the aerial photography. Every attempt was made to create a polygon to capture these disturbance areas.

Project Set-Up

Two types of aerial photography were provided for the project. The photography received was natural color and color infrared (CIR), nominal scale of 1:12,000, dated July 1995. Each type consisted of prints and diapositives. Both sets of imagery were evaluated to determine which film type would be used as the primary source. Upon review it was determined to use the natural color photography as the primary source. The CIR photos were very bright and washed out at rock outcrop areas, causing a glare on adjacent areas.

Upon receipt of the project materials a formal study area had yet to be identified. In order to meet the scheduled field effort, AIS designated a temporary study area boundary for the purposes of field preparation. The temporary study area was based on information gathered during the initial meeting. The park had expressed an interest in having a mile buffer around the park. The park boundary as depicted on the United States Geological Survey (USGS) topographic quadrangle map was used as the basis for the buffer.

A flight line index was created, showing the relationship of the photos to the preliminary study area. The photos were compared to one another to ensure there were no gaps in the imagery and that there was full coverage of the temporary study area.

Preliminary Photo Signature Delineation

A total of 8 photos (non-stereo pairs) were needed to provide full photo coverage of the study area for photointerpretation. Each photo was prepared with one mylar overlay for the photo signature delineations. All attribute codes would be assigned after the photointerpretation field effort. The photo overlays were pin-registered to the photos and labeled appropriately. A study area boundary was determined for each photo, defining the area of photointerpretation. These boundaries were drafted onto the photo overlays and edgematched with adjacent photos to ensure full coverage. Using a mirror stereoscope, the photo signature units were delineated onto the mylar overlays. The delineation of the units was based on signature characteristics including color, tone, texture and relative height. The units were edgematched between photo study areas.

Field Effort

A three day photointerpretation field visit was conducted. As stated earlier, the purpose of the field visit was to familiarize the photointerpreter with the vegetation types and their photo signatures before the actual attributization process. The field crew consisted of Ed Reyes of AIS, and Steve Rolfsmeier and Jim Drake of TNC.

Before the field session, several in-house preparations were made. Each photo was set-up with a field mylar overlay. Registration features (e.g., roads and trails) were drafted onto the overlays. Each photo was reviewed and field sites were chosen representing different signature types, environmental conditions and topography. The sites were drafted onto the field overlays with notations as needed. Multiple sites were chosen to provide alternatives if one or more sites were inaccessible. In addition, the formal study area was received from USGS/ESRI. It contained only three additional areas outside the U.S.G.S. topographic quadrangle depiction of the park. These new areas required some additional delineations of photo signature units.

The field crew conducted on-site field investigations over a three day period. During the field visit, the photointerpreter worked with the field biologists and park personnel to identify the vegetation species found at the park. A field site number was annotated directly onto the photo field overlay, thereby correlating the field site to a specific location and photo signature. A field notebook was used to record pertinent information, e.g., species present, past disturbances, general topography, etc. Ground photos were taken at selected locations and referenced back to the aerial photos and field sites. Sites not previously identified in field preparation were also visited. These included areas between identified sites, and any unusual or notable areas as they

were encountered. Most readily accessible areas were visited, representing most vegetation types within the park.

A brief in-field meeting was held between Ed Reyes, Jim Drake, Steve Rolfsmeier, and Ralph Root to bring up any issues that needed discussion, or answer any questions. Items of discussion included:

- Clarification on the application of height, density and pattern was given by Ralph Root. It was established that height, density, and pattern would apply to the life form of the alliance/community association.

- The importance of the mapping of disturbance vegetation for the park was discussed by Ralph Root. Since mapping of existing vegetation is the goal of the project, and disturbance vegetation is an important aspect of this park, then the disturbance vegetation should be accounted for in the mapping, classification, descriptions, and documentation.

- Ed Reyes demonstrated the manual rectification procedure. Since Scotts Bluff National Monument has such a great local relief and elevation change, parallax within the unrectified photography must be dealt with. Rubber sheeting using a number of control points does not guarantee a best fit overall. Using manual rectification, a photointerpreter controls the decisions for placement of the vegetation units in relation to the orthophoto base signatures. This procedure creates a best fit of the units to the orthophoto base prior to automation. Any fine adjustments can be conducted interactively after the automation process.

- TNC and USGS had a revised classification and description for Scotts Bluff National Monument. The names of the classes had changed, but the vegetation descriptions had not. AIS would receive an updated copy.

As a result of field effort there were several issues involving the classification that needed to be resolved. These issues would result in additions or changes in the current classification and criteria. Resolution of the issues would need to occur before mapping of the alliance/community associations could commence. Because of the nature of these issues and the short schedule for completion of the project, a modification of the mapping procedures was made. Rather than assign the alliance/community association directly to the photo signature unit, it was decided to assign a photo signature code. The inferred alliance/community association would be identified with each photo signature code through the working photo signature key. When the mapping was completed, and the classification finalized, then the alliance/community association would be assigned or linked to each photo signature polygon via a conversion table. This way any changes or additions to the classification or criteria would be made to the working photo signature key as it applies to the photo signature. A potential remapping effort would be avoided.

Photointerpretation of Vegetation

Photointerpretation is the process of identifying map units based on their photo signature.
All land cover features have a photo signature. These signatures are defined by color, texture, pattern, relative height, and tone on the aerial photography. By observing the context and extent of the photo signatures associated with specific vegetation types, the photointerpreter is able to identify and delineate the boundaries of the vegetation. Additional collateral sources (e.g., existing vegetation maps, supplemental photography, soil data, etc.) can be of great utility to the photointerpreter. Understanding the relationship between the vegetation and the context in which they appear is very useful in the interpretation process. Familiarity with regional differences also helps interpretation by establishing a context for a specific area.

The vegetation was mapped using the photo signature code methodology. The photo signature delineation overlay that was created prior to field effort was attached to its corresponding natural color diapositive. Two additional mylar overlays were attached to each photo, one was the photo signature code overlay, the other was the height/density code overlay. The stereo-paired natural color diapositives were viewed through a mirror stereoscope. The height/density and photo signature code overlays were flipped up so that only the photo signature delineation overlay was viewed over the stereo image. Each photo signature unit was analyzed for photo signature description, inferred taxa, context, and inferred alliance/community association. Knowledge gained from the field visit and information from the classification descriptions in association with the photo signature observations formed the basis of decision making. A photo signature code for each polygon was written on the photo signature code overlay. The photo signature code, its color and texture description, the context of the unit, the inferred taxa, and inferred alliance/community association were entered onto the preliminary or working photo signature key. The photo was then analyzed for height and density of the alliance/community association life form. The codes for height and density were written on the height/density code overlay. Where necessary, lines were revised or added to the photo signature delineation overlay. For subsequent photo signature units, if a signature was already characterized in the working key, then the corresponding photo signature code was assigned to the unit. If the photo signature was not yet characterized in the working photo signature key, then it was added to the key. In some cases an existing photo signature characterization was modified. Attribute assignments were based on the mapping criteria and descriptions in the key. Refinements to the methodology and criteria were made as necessary.

Each photo overlay was edgematched to the adjacent corresponding photo overlays to ensure a seamless coverage in the database. Delineations and codes were compared and discrepancies between photos were resolved and corrected on the appropriate mylar overlays. Any uncertain interpretations were flagged on the mylar overlay for review during the quality control task.

Quality Control of Photointerpretations

A separate quality control step was performed for each photo upon completion of the photointerpretation. The photos and their delineation and code attribute overlays were reviewed by a senior photointerpreter. The interpreted overlays were checked for completeness, consistency, and adherence to the mapping criteria and guidelines. For those polygons flagged by the photointerpreter, the reviewer either assigned the appropriate vegetation code and/or discussed the change with the interpreter.

V. DATA CONVERSION

Converting the vegetation delineations to a digital format involved several steps that fall within four main procedures. The first step was the preparation of manuscript maps and attribute code files. The second was the input of the spatial data or geographic locations of the mapped features. The third was the population of the attribute tables or the information that describes the geographic features. Finally, the fourth procedure involved making the data usable for analysis within the GIS.

A note of caution should be stated at this time. One requirement of the scope of work is that the vegetation delineations match the orthophoto image. Another requirement is that the vegetation data be delivered in a Universe Transverse Mercator (UTM) coordinate system. The orthophoto image, however was not in a UTM system. The vegetation data needed to be converted to the orthophoto system in order for adjustment of lines to the image. After completion, the data was converted to

UTM, but the orthophoto image was not. When the vegetation data and the orthophoto image are not in the same system, they will not match up.

The following are descriptions of the broad tasks that apply to the data conversion of vegetation for Scotts Bluff National Monument.

Basemap Production

In order to begin the data conversion process, a hardcopy version of the base was needed. The designated base was the digital black and white orthophoto created for Scotts Bluff County and the monument in 1990. The orthophoto was in two parts, a north and a south area. Portions of the study area outside the monument were not covered by the digital orthophotos. After discussion with USGS it was determined that the USGS topographic quadrangle map would be used as the base for the areas outside the orthophoto coverage.

Creation of the USGS topographic quad base required having a vendor photographically reproduce the topo map onto clear mylar at the mapping input scale, which would be 1:12,000. The aerial photographs were not scaled at exactly 1:12,000. To facilitate rectification, it was decided to determine the actual scale of the photography and have the basemaps created at that scale. The photography was determined to average 1" = 1111'. Likewise, it was decided to output the digital orthophoto hardcopy at 1" = 1111'. An outside vendor provided the topo base, while ESRI provided the orthophoto base.

Manual Rectification

Manual rectification was conducted by attaching a new mylar overlay to each base. The photo signature delineation units were transferred to the overlay through local registration of the photos with the attached photo signature delineation overlay. A small area of the photo was registered to the base at a time. By matching photo image to orthophoto image, or photo image to topo, the delineations were transferred to the base overlay. Because the parallax of the photo is different than that of the base, care was required in transfer. Inconsistent stretching or shortening of the images was common from the photo to the base. In many cases shadows were also a factor. When one area was completed, the photo was shifted to register to another small area. The process continued until the manual rectification and transfer of polygons was complete. Two code attribute overlays were created for each base, one containing photo signature codes, the other the height and density codes. The codes were transferred from the corresponding photo overlays.

A quality control step was performed in order to assure accuracy of the rectification and delineation, and transfer of the codes. A senior interpreter reviewed the overlays for accuracy and completeness of transfer and made the appropriate changes where needed.

Manuscript Map Preparation

The manuscript maps were used to input the spatial component of the vegetation mapping units. A manuscript map suitable for automation was created for each base. Manuscript maps were produced by pin-registering a clean sheet of mylar to each base. The vegetation delineations from the manually rectified overlay were transferred to the new overlay in ink. The manuscript maps were carefully edited to ensure completeness and correctness. The editing included comparing the manuscripts with the original delineations on the aerial photos. Each manuscript map was edgematched to the adjoining sheet assuring a seamless data flow across module (map sheet) boundaries.

Quality Assurance of the Manuscript Map

All final manuscript maps underwent a quality assurance review. The manuscript maps were compared to their corresponding manual rectification overlays to ensure that all line-work had been transferred correctly. Particular attention was given to the quality of the line delineations with respect to gaps and other irregularities.

Sequence Number Assignment

A sequential identification number overlay was produced for each manuscript map. A clean sheet of mylar was pin-registered to each manuscript, and the polygons were labeled in sequence. This was repeated for each base in the study area. The identification number labels were used to tie the spatial file to the keypunched attribute file.

Polygon Attribute Encoding

To expedite the encoding of the vegetation attributes for each polygon, a Quattro Pro file was created for each manuscript map. A separate field was created for the module number, polygon sequence number, photo signature code, height code, and density code attributes. The manuscript map, sequence number overlay and attribute overlays were pin-registered together on a light table. The coder, following the numbers on the sequence number overlay, entered the vegetation attributes for each polygon. During this task the coder verified the accuracy of the sequence number labels. Any errors found on the sequence number overlay were corrected to ensure that each polygon had a unique identifier.

Spatial Data Input/Scanning

The manuscript maps were scanned and converted into ARC/INFO coverages (a single coverage for each manuscript) at ESRI. Prior to any production scanning, test scans of small areas of the data maps were conducted to determine the optimum raster to vector conversion settings. The critical settings that determine the output resolution and completeness are the TOLERANCE and THRESHOLD. The TOLERANCE, which governs the output resolution and is comparable to fuzzy tolerance, would be set to .01 inches (10 feet at 1:12,000 scale). The THRESHOLD is a reflectance measure. It is dependent on the physical characteristics of the data maps and their contents and is determined through testing. Once the THRESHOLD was derived, production scanning of all manuscript maps began.

Assigning Polygon Identifiers

In an earlier step, the vegetation polygons were assigned a unique identifier for each manuscript map. The numbers were sequenced 1 through "n" (4-digit item width) and were drawn on the sequence number overlay. The manuscript map and the sequence number overlay were registered together on the digitizing board. The polygon identifiers were sequentially input as label points. To ensure that all labels points were entered, the processor marked off each label as it was digitized.

Delineation and Sequence Number Edit Plot Quality Assurance

ESRI produced plots of the converted spatial data and sequence numbers (label I.D.s) for each manuscript. The plots were checked by AIS for cartographic quality of the arcs defining the polygon features and the accuracy of the label I.D. assignments. The plots were overlaid to the manuscript maps to verify that the scanned data was not distorted beyond .02 map inches. Other problems were noted on the plots, such as overshoots and undershoots, missing lines, premature convergence of polygon boundary lines that intersected arcs at acute angles, and incorrect sequence number assignments.

The corrected plots were delivered back to ESRI. Processors conducted interactive ARCEDIT sessions to make the necessary corrections to the coverages.

Creation of Topology

Topology is the mathematical procedure for explicitly defining spatial relationships. In the case of maps, topology defines connections between features, identifies adjacent polygons, and can define one feature such as an area, as a set of other feature types (i.e., lines). A topological database has several advantages: efficient data storage, faster processing, and the ability to perform analysis, such as modeling transportation networks or overlaying geographic features on one another.

Once the manuscript map's polygon boundaries and label points had been input into the computer, the ARC/INFO software CLEAN command was used to create the "coverage topology." The CLEAN fuzzy tolerance was set to .002 inches to preserve the required data resolution. When other coordinate edits were made to a coverage after the CLEAN command was run, topology was recreated utilizing the BUILD command.

Label Entry Error Processing

Label errors were identified by using the LABELERRORS command in ARC through an ARCEDIT session. Any label errors identified were corrected by entering the missing label number and placing it within the correct polygon. Once all the errors were corrected, the coverage was ready for the polygon rectification process.

Georeferencing and Digital Registration of Data

The georeferencing and digital registration of the data was a multi-step process. The data had to be transformed into real world coordinates and the data had to be adjusted to fit the orthophoto image. These steps were all performed digitally using ARCEDIT.

- Conversion to "Real-World" Coordinates

  This task involved the transformation of the database from "digitizer inches" into "real world" coordinates. The initial vector file contained coordinates stored as digitizer inches that does not allow the data to be used effectively. To utilize geographic data, it must be converted into a common coordinate system. The coordinate system used was the Universal Transverse Mercator (UTM), Zone 13, NAD83 Coordinate System. All coordinates were in meter units.

  The first step was the creation of a master tic file, linking features on the orthophoto to the same features in the polygon coverages. Wherever possible, easily identified points were chosen to ensure a more accurate transformation. Four to six points were chosen per coverage and labeled with a tic number I.D. The points were then transformed into real world coordinates, x and y values only (the orthophotos did not have a z value).

- Compare Transformed Delineation Coverages to Digital Image

  The transformed coverages were then compared to the digital orthophotos. Manual rectification had been chosen instead of digital rectification because it was assumed that a minimal amount of adjustment would need to be performed once the coverages were transformed. This was based on the fact that the photointerpretations were created from entirely different images as the digital orthophotos. Also, parallax differences between the photos and the orthophotos would not be consistent. Human observations and decisions were more likely to produce a better rectified product, thus minimizing any subsequent digital rectification.

  However, upon comparison of the transformed coverages to the orthophoto, it was apparent that the data did not fit the image well in some places. As a result, interactive ARCEDIT sessions were conducted to improve the registration of the data to the digital image. These sessions were composed of several adjustment steps, described below:

  - Coarse Adjustment

    The first series of ARCEDIT sessions consisted of coarse adjustments. Coarse adjustments are used to register data over large areas. For Scotts Bluff National Monument, this step was performed on areas with gross registration discrepancies between the image and the polygon boundaries. On-screen, a series of links (10 - 30 links per view) between the delineations and the orthophoto were created. The ADJUST command was performed and the linework for the entire coverage was adjusted. The coarse adjust corrected some of the registration problems but more local adjustments were still required.

  - Local Adjustment

    The second series of ARCEDIT sessions were the local adjusts. This adjustment was performed over a smaller area and was used to fine tune the registration of the data to the digital orthophoto. A window was created on-screen and enlarged for a selected area. As with the coarse adjust, a number of links were created. A LIMITADJUSTBOX was then defined encompassing all of the links. The ADJUST command was performed and the linework within the defined area was adjusted. This was repeated as necessary across the entire coverage. Although this step greatly improved the rectification of the linework to the digital orthophoto there were still areas requiring further adjustment. Polygon label I.D. points were also adjusted as needed.

- Specific Adjustment

  The third ARCEDIT session was the specific adjust. The data was again compared to the orthophoto image on a polygon by polygon basis. Special attention was given to obvious feature boundaries such as land use/vegetation and land/water interfaces. If necessary a specific adjust was performed. The vertices of the line segments were modified (moved, added, or deleted) until the linework conformed to the orthophoto image. In some instances, entire line segments were deleted and redigitized on-screen. This process was repeated until all of the coverages were completed.

Joining of Attribute and Spatial Data

The Quattro Pro code files were converted into INFO files. Once converted they were related to the feature attribute table, by the sequence number found in both files. An INFO item, named "sequence number" was added to the feature attribute table. The sequence number for each polygon was calculated to equal its coverage I.D. number. The ARC/INFO command JOINITEM was used to join the code file to the feature attribute table. Each spreadsheet file was joined with its corresponding coverage. Each variable interpreted from the aerial photography was assigned a unique item (field). A total of three coverages were created.

Code Verification

Code verification involved running each coverage attribute file through a series of ARC/INFO commands that checked for invalid codes. These commands produced listings that aided in identifying abnormal codes. The errors were checked against the vegetation delineation and attribute overlays. Corrections were made to the listings and input into the database.

ESRI produced code verification plots of the photo signature code, height, and density attributes. The plots were checked by AIS for coding errors that may have occurred during the polygon attribute encoding step. The plots were overlaid on the manuscript map with attached corresponding code attribute overlay created in the manual rectification step. Code changes were noted on the plot. The corrected plots were delivered back to ESRI for edit of the attribute files.

Edgematching

Since the study area was composed of multiple coverages, the coverages needed to be coordinate edgematched to ensure seamless line across coverage boundaries. The three coverages were edgematched using procedures in the ARC editor linking the nodes from one coverage to the nodes of the adjoining coverage. Adjustments were made when necessary. This procedure was done with the digital orthophoto as a backdrop to the vegetation delineations.

VI. CONVERSION OF PHOTO SIGNATURE CODE TO THE NATIONAL CLASSIFICATION

The final product for the Scotts Bluff National Monument mapping effort was an alliance/community association vegetation map of the study area. A relate table was used to convert the vegetation photo signature codes in the database to the alliance/community association classification.

The first step in the code conversion process was the creation of a table linking the photo signature code to the appropriate alliance/association and land use class. The conversion of photo signature to alliance/community association had been identified in the working photo signature key during the photointerpretation process. The information was keypunched into a Quattro Pro code file. The file contained three fields, composed of photo signature, alliance/community association, and land use codes. The Quattro Pro file was converted to ASCII, then converted into an INFO relate table.

The information in the relate table was linked to the coverage attributes, thereby relating the photo signature code in the coverage attribute to the photo signature code in the relate table. The items from the relate table were then added to the coverage attribute table and populated.

Once the relate between the photo signature codes and the alliance/community association classes was completed and the attribute items populated, a final alliance plot was created. The plot was compared back to the original natural color photos and photo overlays and reviewed for accuracy and consistency of alliance class assignments. Corrections to the alliance assignments were made to the database.

The pattern attribute was mapped by interpreting the pattern of the corresponding life form of each alliance/community association polygon. The units were drafted onto an overlay of the manuscript map. The pattern attribute was then input by digicoding to each existing polygon. An edit plot was created for review.

The final coverage of the vegetation database was delivered to ESRI for input into the final project database structure.

A second mapping effort was contracted to the Bureau of Reclamation in 1996-7 to compare the results of two independent mapping projects using the same methodology and classification. An accuracy assessment was conducted in August 1997 to test the accuracy of the the two spatial databases.

The accuracy assessment (AA) at Scottsbluff National Monument was designed for use with two independent mapping efforts (AIS/ESRI and Bureau of Reclamation) intended as a benchmarking study. Both maps were generated using basically the same vegetation description, classification systems, aerial photography, and orthophoto basemap.

In order to avoid two repetitive ground field efforts, the sampling plan was devised from a combination of both vegetation maps. Using OR logic, overlays were created using both maps as input for each class, and random samples were developed for each class in excess of 30 polygons. Where there were less than 30 polygons sample sites were selected non-randomly from each polygon (i.e. a 100% sample).

A total of 512 ground sampling sites were developed from a total of 21 vegetation and land cover classes which are represented on both vegetation maps.

Using GIS tools, an ASCII file was generated with ground coordinates representing each of these sites. The 512 sets of coordinates were appropriately re-formatted and directly downloaded as waypoints in three North American Rockwell PLGR GPS receivers.

During the week of August 4, 1997 three field crews of two persons each worked together at the monument in a coordinated effort to identify vegetation/cover types at each of the sites. The field crews had a paper map showing the location of the plots and the polygon boundaries (but not attributes) overlaid on topographic data. One team member operated the GPS receiver to navigate to the site, and the other identified the vegetation/cover type and provided a general physical description of the site environs. Sites were considered to be circle with a radius of 50 m. from the coordinate point. Where 2 or more vegetation/cover types occurred, or there was a mosaic of types, all were described within the 50 m. radius of the site coordinate.

Upon completion of the accuracy assessment field work, field teams were unable to access 9 sites, and 9 additional ones did not fit within the vegetation classification scheme, leaving a total of 494 sites for comparison with vegetation/cover classes in both of the vegetation maps.

These accuracy assessment data were then applied to each of the two vegetation maps after grouping classes of each to bring them into common agreement. An explanation of the groupings is provided in the metadata description for each individual map.

A preliminary accuracy assessment analysis was completed on the two spatial databases, comparing the accuracy assessment classes with the spatial data. Neither map met the USGS-NPS Vegetation Mapping Program minimum standards of classification accuracy of 80%. Analysis of the contingency tables for the maps showed accuracy per class of 5- - 60%

The following possibilities exist which could explain why the accuracy assessment figures are not up to the program standards of 80%

a. The classes were mapped incorrectly

b. The accuracy assessment sites were described/identified incorrectly

c. Geographic locational errors caused confusion with a neighboring type

d. Problems in development of the classification system and keys leaving types which are not described or mapped, but really exist in the field.

e. The ground type actually changed between the time of mapping (photo acquisition date and mapper field checking) and the time of accuracy assessment field data collection.

f. Photo interpreters made different estimates of woodland/shrub canopy densities, resulting in different classes.

Reasons "e" and "f" are probably the primary causes of the low AA results, and that d, c, b and a, may all be true but to a much lesser extent. Both BOR and ESRI employed competent photo interpreters who spent significant time in the field making comparisons of vegetation types with the same aerial photographs. Although wrong identification of vegetation classes certainly is possible, there is general agreement between accuracy figures between the maps. With some exceptions certain classes were consistently high or low in accuracy. So either both maps were jointly wrong, or there was an error in identifying the type by the AA crew, or phenological differences may have occurred.

A meeting was held in February 1998 to resolve the problems between the two spatial databases and the accuracy assessment data. Attendees included the primary photointerpreters from AIS and BOR, the Park natural resources manager, a representative from the NPS Prairie Park Cluster Office, and representatives from USGS, and the NPS I&M program.

AIS performed the changes to the databases that were agreed to by the participants at the meeting. The changes were:

A Criteria/Crosswalk Analysis

* The criteria clarifications resulting from the Denver meeting of February 19 will be applied to a new crosswalk for the purpose of identifying specific polygons for photo interpretive analysis. The criteria clarifications are summarized below:

* Add Pinus ponderosa savanna community association defined as 10-25% coniferous trees, <10% of trees Juniperus scopulorum, >90% of trees Pinus ponderosa.

* Adjust break between trees and shrubs, and shrubs and herbaceous. For trees, if have 25% trees, or thereabout ±5%, code as tree community rather than shrub community. If have 25% shrubs or thereabout ±5%, code as shrub community rather than herbaceous community.

* Re-evaluate Andropogon hallii-Calamovilfa longifolia Herbaceous Vegetation community association. There may be more area identified as such than should be. Some of these areas may be Stipa comata-Bouteloua gracilis-Carex filifollia Herbaceous Vegetation community association.

* Re-evaluate the area of the park between the Gering Canal and the railroad right-of-way for Pascopyrum smithii Herbaceous Vegetation vs. Eroding Great Plains Slopes Sparse Vegetation, Stipa comata-Bouteloua gracilis-Carex filifolia Herbaceous Vegetation vs. Andropogon hallii-Calamovilfa longifolia Herbaceous Vegetation, and Pascopyrum smithii Herbaceous Vegetation vs. Symphoricarpos occidentalis Shrubland.

* Re-evaluate Rock Outcrop/Prairie Mosaic areas for >25% herbaceous cover. These areas should be mapped as Stipa comata-Bouteloua gracilis-Carex filifolia Herbaceous Vegetation.

The photo signature code table contains information on sparse or rare tree, sparse or rare shrub situations, and taxa that can be used to flag polygons for photo interpretive analysis. The photo signature code table will be used to create a new crosswalk table that will serve as a means of producing an interim working vegetation map.

Data Processing

The crosswalk table information will be input into an INFO relate table that will link the photo signature to the community association. Plot AMLs will be written to create interim working products. The interim working vegetation map products will include community associations, photo signature polygons, photo signature codes, point plot site locations, point observation site locations, and point accuracy assessment site locations. These products will be produced at the photo scale of 1:12,000, and at a larger scale for legibility.

Photo Interpretation Analysis

The polygons that were identified for photo interpretive analysis through the crosswalk will be analyzed for their proper community association assignment based on the new criteria. In addition, a regional photo interpretive evaluation will be done for two areas.

The area of the park between the Gering Canal and the railroad right-of-way will be evaluated for Pascopyrum smithii Herbaceous Vegetation vs. Eroding Great Plains Slopes Sparse Vegetation, Stipa comata-Bouteloua gracilis-Carex filifolia Herbaceous Vegetation vs. Andropogon hallii-Calamovilfa longifolia Herbaceous Vegetation, and Pascopyrum smithii Herbaceous Vegetation vs. Symphoricarpos occidentalis Shrubland.

The bluff areas of the park mapped as Rock Outcrop/Prairie Mosaic areas will be evaluated for >25% herbaceous cover. These areas should be mapped as Stipa comata-Bouteloua gracilis-Carex filifolia Herbaceous Vegetation.

Other Analyses

The revised vegetation map will be compared with the point site information. This analysis will be documented. The site information includes:

* Plot site information
* Observation site information
* PI field site information
* Accuracy assessment site information

As additional check for further analyses, the revised vegetation map will be generally compared with the BOR map to see if there are any other areas which may require adjustment.

Final Revision, QC, and Processing

All revisions to the interim vegetation map will be identified and changes made to the digital file. Corresponding modifications to the Height, Density, and Pattern layers will also be identified and changed. A new refined vegetation map will be plotted and will undergo quality control through visual check against the photography. Any final changes will be made to the file. A new file and hardcopy vegetation map will be delivered to BRD. The file will include Photo signature code, Alliance/Community Association, Height, Density, Pattern, Land Use.

A final spatial database was delivered to BRD in July 1998, along with a spreadsheet comparing the spatial data to the accuracy assessment data. Again, the accuracy levels did not come close to 80% for most classes.

At this point, a detailed analysis was undertaken by USGS scientists to resolve the discrepancies between the accuracy assessment data and the spatial data. All accuracy assessment points that did not agree with the spatial data were plotted on a paper map, and the aerial photographs and AA field forms were examined to try to determine which one was correct. There were 3 types of disagreement that existed: 1) the accuracy assessment point was in error, 2) the photointerpretation was in error, and 3) no obvious error could be discerned in either data source. Where there was obvious error in the accuracy assessment data, that code was immediately change. The error was usually caused by locational error in the GPS data or by the addition of a sparse forested herbaceous type, which did not exist during the accuacy assessment. An example of obvious AA error was a point in a sparse forested herbaceous type that was called an herbaceous type in the AA data.

Vegetation Inventory and Mapping Program
Scotts Bluff National Monument
Vegetation Refinement Classification
June 15, 1998

ALLIANCE/COMMUNITY ASSOCIATION WOODLAND

01 = Juniperus Scopulorum Woodland Alliance
Juniperus scopulorum / Oryzopsis micrantha Woodland

02 = Pinus Ponderosa Woodland Alliance
Pinus ponderosa / Juniperus scopulorum Woodland

03 = Populus Deltoides Temporarily Flooded Woodland Alliance
Populus deltoides - (Salix amygdaloides) / Salix exigua Floodplain Woodland

25 = Pinus Ponderosa Weeded Medium-Tall Herbaceous Vegetation
Pinus ponderosa - Schizachyrium scoparium Wooded Herbaceous Vegetation

SHRUBLAND

04 = Cercocarpus Montanus Shrubland Alliance
Cercocarpus montanus / Bouteloua curtipendula Shrubland

05 = Salix Exigua Temporarily Flooded Shrubland Alliance
Salix exigua Shrubland

06 = Symphoricarpos Occidentalis Temporarily Flooded Shrubland Alliance
Symphoricarpos occidentalis Shrubland

HERBACEOUS

07 = Andropogon Gerardii - (Calamagrostis Canadensis, Panicum Virgatum) Herbaceous Alliance
Andropogon gerardii - Calamagrostis canadensis - Helianthus grosseserratus Herbaceous Vegetation

08 = Andropogon Hallii Herbaceous Alliance
Andropogon hallii - Calamovilfa longifolia Herbaceous Vegetation

09 = Alliance Undefined
Kochia scoparia/Bromus spp. Early Seral Community

10	=	Alliance Undefined Mixed Grass Prairie (Reseeded/Restored)
11	=	Pascopyrum Smithii Herbaceous Alliance Pascopyrum smithii Herbaceous Vegetation
12	=	Stipa Comata - Bouteloua Gracilis Herbaceous Alliance Stipa comata - Bouteloua gracilis / Carex filifolia Herbaceous Vegetation
13	=	Typha (Angustifolia, Latifolia) - (Scirpus Spp.) Semipermanently Flooded Herbaceous Alliance Typha spp. Inland Great Plains Herbaceous Vegetation
14	=	Carex Spp. - Typha Spp. Saturated Herbaceous Alliance Typha spp. - Equisetum hyemale / Carex spp. Seep Herbaceous Vegetation

SPARSELY VEGETATED / NON-VASCULAR

15	=	Open Bluff / Cliff Sparse Vegetation Inland Siltstone Bluff - Cliff
16	=	Rock Outcrop / Butte Sparse Vegetation Siltstone - Clay Butte Sparse Vegetation
17	=	Sand Flats Temporarily Flooded Sparse Vegetation Riverine Sand Flats - Bars Sparse Vegetation
18	=	Large Eroding Cliffs Sparse Vegetation Eroding Great Plains Badlands Sparse Vegetation
19	=	Small Eroding Cliffs / Banks Sparse Vegetation Eroding Great Plains Slopes Sparse Vegetation

COMPLEX CLASSES

20	=	Rock Outcrop/Prairie Mosaic
21	=	Cliff/Rock Outcrop/Prairie Mosaic

MISCELLANEOUS CLASSES

22	=	Unvegetated Disturbance
23	=	Water

24	=	Unvegetated Land Use Disturbance

CHARACTERISTICS HEIGHT

1	=	<0.5 meters
2	=	0.5 - 2 meters
3	=	2 - 5 meters
4	=	5 - 15 meters
5	=	15 - 35 meters
6	=	35 - 50 meters
7	=	>50 meters
9	=	Not Applicable

ABSOLUTE CROWN DENSITY

1	=	Closed/Continuous > 60 %
2	=	Discontinuous 40% - 60%
3	=	Dispersed 25% - 40%
4	=	Sparse 10% - 25%
5	=	Rare 2% - 10%
9	=	Not Applicable

PATTERN

1	=	Evenly Dispersed
2	=	Clumped/Bunched
3	=	Gradational/Transitional
4	=	Alternating
9	=	Not Applicable

LAND USE

100	=	Urban or Built-Up		
		110	=	Residential
		120	=	Commercial
		130	=	Industrial
		140	=	Transportation, Communication, and Utilities
		150	=	Mixed Commercial and Industrial
		160	=	Mixed Urban
		170	=	Under Construction
		180	=	Open Space and Recreation
		190	=	Vacant within Urban Context
200	=	Agriculture		
300	=	Mining		
400	=	National Park/Monument Facilities		

401	=	Visitor Center, Ranger Residence, and Associated Facilities
402	=	Visitor Center Mowed Disturbed Area
403	=	Visitor Center Parking Area
404	=	Scotts Bluff Parking Area
405	=	Scotts Bluff Paved Road
406	=	Paved Road and Associated Disturbance Area, Cut and Fill Area
407	=	Railroad and Associated Maintained Area, Disturbance Area, Cut and Fill Area
408	=	Not used
409	=	Canal/Ditch and Associated Maintenance Road, Disturbance Area, Cut and Fill Area, and Adjacent Seepage Vegetation
410	=	Unvegetated Disturbance, Bare Ground

500	=	Water
600	=	Vacant